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Sir:

Transmitted herewith for filing with Express Mail Label Number EL590678658US is the patent application of

Applicant: Ling Thio

Title: System and Method for Measuring Network Round Trip Time by Monitoring Fast-Response Operations

Enclosed are:

[x] 17 pages of specification, claims and abstract.
[x] 6 sheets of [X] informal [ ] formal drawing(s).
[ ] Declarations and powers of attorney.
[ ] An assignment transmittal.
[ ] Assignments of the invention to
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[ ] A certified copy of a ________________ application.
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Basic Fee				$345.00			$690.00
Total Claims	16 - 20 =*	0	x $9 =	$		x $18 =	$0.00
Indep. Claims	4 - 3 = *	1	x $39 =	$	or	x $78 =	$78.00
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Respectfully submitted,

Dated: 9/29/00

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SYSTEM AND METHOD FOR MEASURING NETWORK ROUND TRIP TIME BY MONITORING FAST-RESPONSE OPERATIONS

Ling Thio

CROSS-REFERENCE TO RELATED APPLICATION

This application is related to, and claims the benefit of, U.S. Provisional Application No. 60/156,981, entitled "Method for Measuring Network Round Trip Time by Monitoring Fast-Response Operations," filed October 1, 1999, which is hereby incorporated by reference.

BACKGROUND

1. Field of the Invention

The present invention relates generally to computer networks, and more particularly to a system and method for measuring network round trip time.

2. Description of the Prior Art

Recent growth in and an increasing reliance on networked computer applications have generated a need for network performance monitoring tools. Measuring the performance of networked systems is a significant consideration of users, designers, and manufacturers of these systems. Such monitoring tools allow system administrators and others to observe network responses to varying loads and conditions, to identify

and diagnose problems in the communications paths, and to optimize network architectures to avoid bottlenecks and other congestion-causing conditions. There is a specific need for tools which measure delays associated with application execution and determine which portion of the delay is attributable to the network, which portion is attributable to the server, and so on.

Network performance monitoring tools are generally configured to measure and display various parameters characterizing communications between or among a plurality of network endpoints. In TCP/IP-based networks, one such parameter is the network Round Trip Time (RTT).

FIG. 1 depicts an exchange of packets between a client computer 100 and a server computer 110 over a network 120. At time t_{C1}, client computer 100 sends a packet 130. By way of example, packet 130 may represent a database search query. Packet 130 travels on network 120 and arrives at server computer 120 at time t_{S1}. During a Server Delay (SD) time, packet 130 is delivered to a database engine residing on server computer 110, which processes the search query and responsively generates a search result. At time t_{S2}, the server computer 110 sends a response packet 140 containing search results. Packet 140 travels over network 120 and arrives at client computer 100 at time t_{C2}.

The total transaction time of the foregoing transaction is given by the equation:

$$TT = SD + RTT$$

where TT is the transaction time. In accordance with the example depicted in FIG. 1:

$$RTT = (t_{S1}-t_{C1}) + (t_{C2}-t_{S2}).$$

This example and many prior art packages require that both network endpoints (i.e., both the client computer 100 and the server computer 110) be instrumented in order to monitor the various times. However, a problem exists where network performance is to be monitored at only one of two network endpoints. For example, it may be desirable to locate the network performance-monitoring tool at client computer 100. To accurately calculate the RTT, however, it is necessary to have knowledge of the server computer 110 packet receive and send times, t_{S1} and t_{S2}, which will not be available to client computer 100. Therefore, there is a need for a system and method for measuring network round trip time at a single network endpoint.

SUMMARY

The present invention provides a system and method for measuring network round trip time by monitoring fast-response operations at one network endpoint. The system of the invention includes a network monitoring and analysis engine on the network endpoint which monitors a sent packet for a fast-response operation. If a fast-response operation is detected, then the network endpoint, typically a client computer, will assume a server computer processed the packet substantially instantaneously. Thus, the processing time at the server computer is estimated to be zero. The round trip time can then be approximated as the difference between when the packet was sent and when a response packet was received by the client computer.

The invention therefore provides a method for measuring network round trip time at one endpoint which is computationally efficient, easily implemented, and may be utilized with any networked application.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a diagram showing a conventional exchange of packets during a transaction between a client and a server;

FIG. 2 is a diagram of an exemplary network system for implementing the invention;

FIG. 3 is a block diagram of a client computer for implementing the invention;

FIG. 4 is a diagram of an exchange of packets during a transaction between a client and a server with a fast-response operation;

FIG. 5 is a block diagram of one embodiment of the monitoring and analysis engine of FIG. 3, according to the invention; and

FIG. 6 is a flowchart of method steps for measuring round trip time, according to one embodiment of the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. 2 depicts an exemplary network system 200 for implementation of the present invention. A plurality of computers, including, for example, a client computer 202 and a server computer 210, are coupled for intercommunication by a network 220 implementing the TCP/IP protocol. Network 220 is of arbitrary topology and complexity, and client and server computers 202 and 210 may be connected by a variety of network interfaces to network 220. Network 220 may comprise a public packet-switched network, such as the Internet, or alternatively may comprise a private TCP/IP based network, known colloquially as an intranet.

In networked applications, data processing functions are distributed between the client computer 202 and server computer 210. For example, a networked database application locates software for front-end functions, such as a user interface, at client computer 202, while software for back-end functions, such as processing SQL statements, is located at server computer 210. Requests and data generated by the front and back ends are periodically communicated between client computer 202 and server computer 210 over network 220.

In a typical network transaction, client computer 202 requests specific data from server computer 210 via a data exchange through network 220. Server computer 210 then processes the request and delivers data to client computer 202. The initial request from client

computer 202 and the data from server computer 210 pass through various routers and transmission links in network 220. The exact path of the transmissions through network 220 is typically unknown, and may be different for each connection between client and server computers 202 and 210, respectively.

FIG. 3 is a block diagram showing exemplary components of client computer 202. The client computer 202 includes a central processing unit (CPU) 302, video display 304, video display interface 306, memory 308 and network interface 310 all coupled either directly or indirectly to system bus 312. CPU 302 executes program instruction and manages communication between the various components of client computer 202.

Video display 304, coupled to video display interface 306, presents text, graphics and other visual information to a user. This information may also include results of the network round trip time analysis.

Memory 308 may comprise any one or a combination of volatile memory such as RAM, non-volatile memory such as ROM, or storage devices such as a magnetic hard drive. Memory 308 stores program instructions and data for processing by CPU 302. Such instructions and data may include, but are not limited to, application 314, TCP/IP stack 316, packet duplicator engine 318, and monitoring and analysis engine 320. Application 314 may include, without limitation, a database front-end, a browser or e-mail client, or a transaction processing application which transmits and/or receives data or requests over network 220.

TCP/IP stack 316 implements various functions of the TCP/IP protocol suite. The operation of TCP/IP stack 316, which may be incorporated into the client computer 202 operating system, is well known in the art and thus will not be described in detail herein.

Packet duplicator engine 318 utilizes well-known techniques to intercept and duplicate sent and received packets processed by TCP/IP stack 316. The duplicated packets are then delivered to the monitoring and analysis engine 320, which will be discussed in more detail in connection with FIG. 5.

Network interface 310 enables connection of client computer 202 to network 220. Network interface 310, conventionally, may comprise a modem, Ethernet card, or a digital subscriber line (DSL).

FIG. 4 depicts an exchange of packets representative of a fast-response operation. At time t_{C1}, client computer 202 sends a request packet 400 over network 220. Packet 400 is received at server computer 210 at time t_{S1}. Server computer 210 then, substantially instantaneously, processes the information contained in packet 400. Subsequently, at time t_{S2}, server computer 210 sends a response packet 410 containing a response to client computer 202. Client computer 202 at time t_{C2} receives packet 410.

The present invention measures network round trip time by monitoring for fast-response operations, which are operations involving client requests which may be processed relatively quickly by server

computer 210. If the client request involves a fast response operation, server computer 210 processes the information contained in packet 400 substantially instantaneously. Consequently, the server delay is substantially less than the round trip time (SD<<RTT), and so the RTT can be closely approximated by calculating the difference between the time t_{C1} the request is sent by client computer 202 and the time t_{C2} the response from server computer 210 is received by client computer 202. Thus, the round trip time with a fast response operation is approximated by the equation:

$$RTT \sim t_{C2} - t_{C1}.$$

Subsequently, the total transaction time is calculated by the equation:

$$TT = SD + RTT$$

where SD is assumed to be negligible, resulting in:

$$TT \sim RTT \quad \text{or} \quad TT \sim t_{C2} - t_{C1}.$$

Each application will have a characteristic set of fast-response operations associated therewith. For SQL database applications, exemplary fast-response operations include OPEN_CURSOR and CLOSE_CURSOR operations. Other fast-response operations are known to those having ordinary skill in the art.

FIG. 5 depicts in block form one embodiment of the monitoring and analysis engine 320 according to the invention. Preferably, network interface 310 sends and receives packets over the network 220 (FIG. 2),

and packet duplicator 318 is configured to intercept and duplicate these sent and received packets. Duplicated packets are then delivered to a fast-response operation analyzer 510 in the monitoring and analysis engine 320. Fast-response operation analyzer 510 is advantageously operative to examine each duplicated packet to determine if the packet contains information representative of a fast-response operation. Fast-response operation analyzer 510 may conventionally attempt to match information contained in the examined packet to user-supplied or automatically generated fast-response time operation definitions 520. The definitions 520 may list characteristic information associated with fast-response operations of the monitored application(s).

Upon detection of a fast-response operation, monitoring and analysis engine 320 is operative to calculate an RTT 530 corresponding to the detected fast-response operation by determining the difference between t_{C2} and t_{C1} (i.e., subtracting the time at which packet 400 (FIG. 4) is sent from the time at which packet 410 (FIG. 4) is received at client computer 202).

FIG. 6 is a flowchart 600 depicting a preferred method for calculating round trip times, according to the invention. In block 610, a client computer 202 (FIG. 2) determines the time t_{C1} a request packet 400 (FIG. 4) is sent to a server computer 210 (FIG. 2).

Next, the client computer 202 determines if a fast response operation is contained in the packet 400 in block 620. Fast-response

operation analyzer 510 (FIG. 5) examines a duplicate copy of the sent packet 400 for information representative of a fast-response operation. If no fast-response operation is detected, then the method is not applicable for measuring network round trip time. However, if a fast-response operation is detected, then in block 630 the client computer 202 determines the time t_{C2} a response packet 410 (FIG. 4) is received by the client computer 202.

Finally, in block 640, the client computer 202 calculates the round trip time, RTT. Because the server computer 210 substantially instantaneously processes the packet 400 with a fast-response operation, the time between t_{S1} when the server computer 210 receives the packet and the time t_{S2} the server computer 210 sends the response packet is deemed negligible. Thus, the round trip time, and subsequently the transaction time, is estimated to be the difference in time between when the client computer 202 sends the request packet 400 and when the client computer 202 receives the response packet 410.

The invention has been explained above with reference to a preferred embodiment. Various features and aspects of the above-described embodiment may be used individually or jointly. Further, although the invention has been described in the context of its implementation in a particular environment and for particular applications, those skilled in the art will recognize that its usefulness is not limited thereto and that the invention can be beneficially utilized in

any number of environments and implementations. Therefore, these and other variations upon the preferred embodiments are intended to be covered by the invention, which is limited only by the appended claims.

WHAT IS CLAIMED IS:

1. A system for measuring network round trip time, comprising:

a processor; and

a monitor and analysis engine coupled to the processor for determining the presence of a fast-response operation and calculating the round trip time.

2. The system of claim 1 wherein the monitor and analysis engine includes a fast response operator analyzer for detecting the presence of the fast-response operation.

3. The system of claim 1 wherein the monitor and analysis engine includes fast-response time operation definitions which list characteristic information associated with fast-response operations.

4. The system of claim 3 wherein the definitions are user-supplied.

5. The system of claim 3 wherein the definitions are automatically generated.

6. The system of claim 1 further comprising a packet duplicator for intercepting and duplicating sent and received packets, and forwarding the duplicated packets to the monitoring and analysis engine for analysis.

7. The system of claim 1 further comprising a display device for displaying graphical representations of the round trip time.

8. A method for measuring network round trip time, comprising the steps of:

determining if a sent packet indicates a fast response operation; and

if the packet does indicate a fast response operation, calculating a round trip time.

9. The method of claim 8 wherein the step of determining includes duplicating the packet.

10. The method of claim 9 wherein the duplicated packet is forwarded to a monitoring and analysis engine.

11. The method of claim 8 further comprising the step of identifying a time when the packet was sent and identifying a time when a response packet was received.

12. The method of claim 11 wherein the round trip time is calculated by determining the time difference between when the packet was sent and when the response packet was received.

13. The method of claim 8 further comprising the step of assuming that a packet indicating a fast-response operation was substantially instantaneously processed at a server computer.

14. The method of claim 8 further comprising the step of providing a representation of the round trip time via a display device to a user.

15. A system for measuring network round trip time comprising:

means for determining if a packet indicates a fast response operation; and

means for calculating a round trip time if the packet does include a fast response operation.

16. A computer-readable medium storing program instructions for causing a computer to measure network round trip time, by performing the steps of:

determining if a packet indicates a fast response operation; and

if the packet does indicate a fast response operation, calculating a round trip time.

SYSTEM AND METHOD FOR MEASURING NETWORK ROUND TRIP TIME BY MONITORING FAST-RESPONSE OPERATIONS

ABSTRACT OF THE DISCLOSURE

A system and method is provided for measuring network round trip time by monitoring fast-response operations at one network endpoint, typically a client computer. A client computer of the system includes a network monitoring and analysis engine which monitors a sent packet for a fast-response operation. If a fast-response operation is detected, then the client computer assumes a server computer processed the packet substantially instantaneously. Thus, the processing time at the server computer is neglected as zero. The round trip time can then be approximated as the difference in time between when the client computer sent the packet and when the client computer received the response packet.

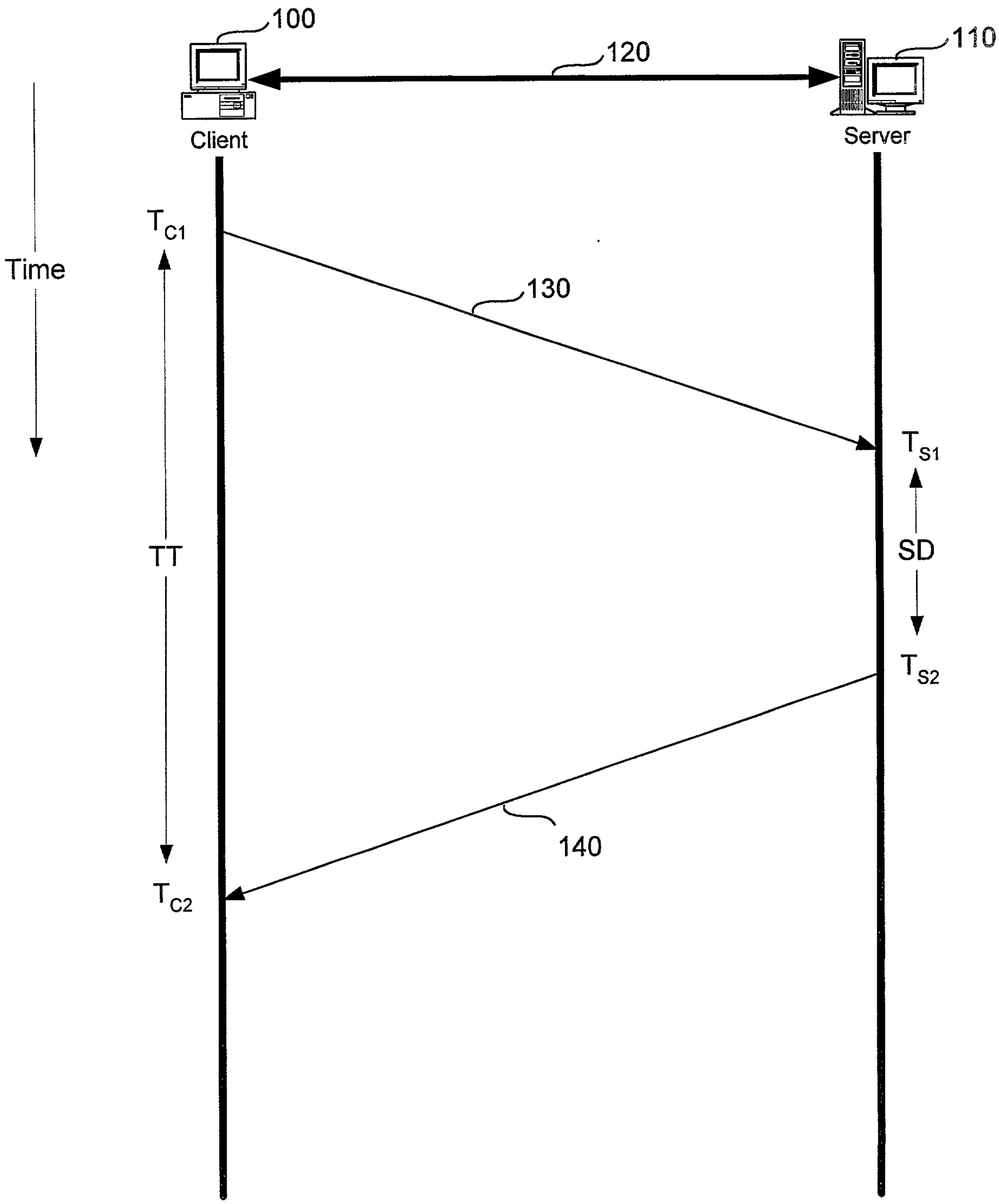


FIG. 1

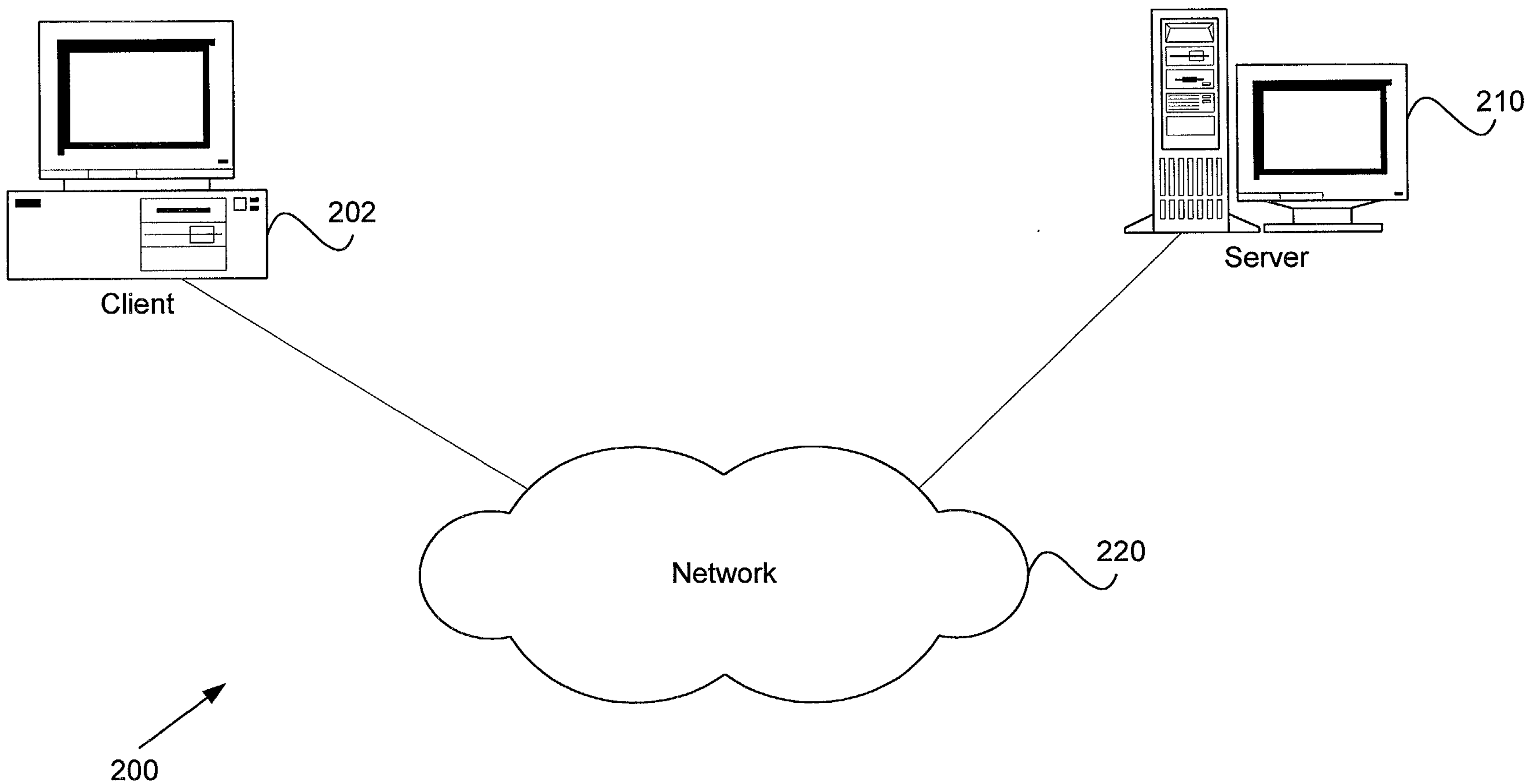


FIG. 2

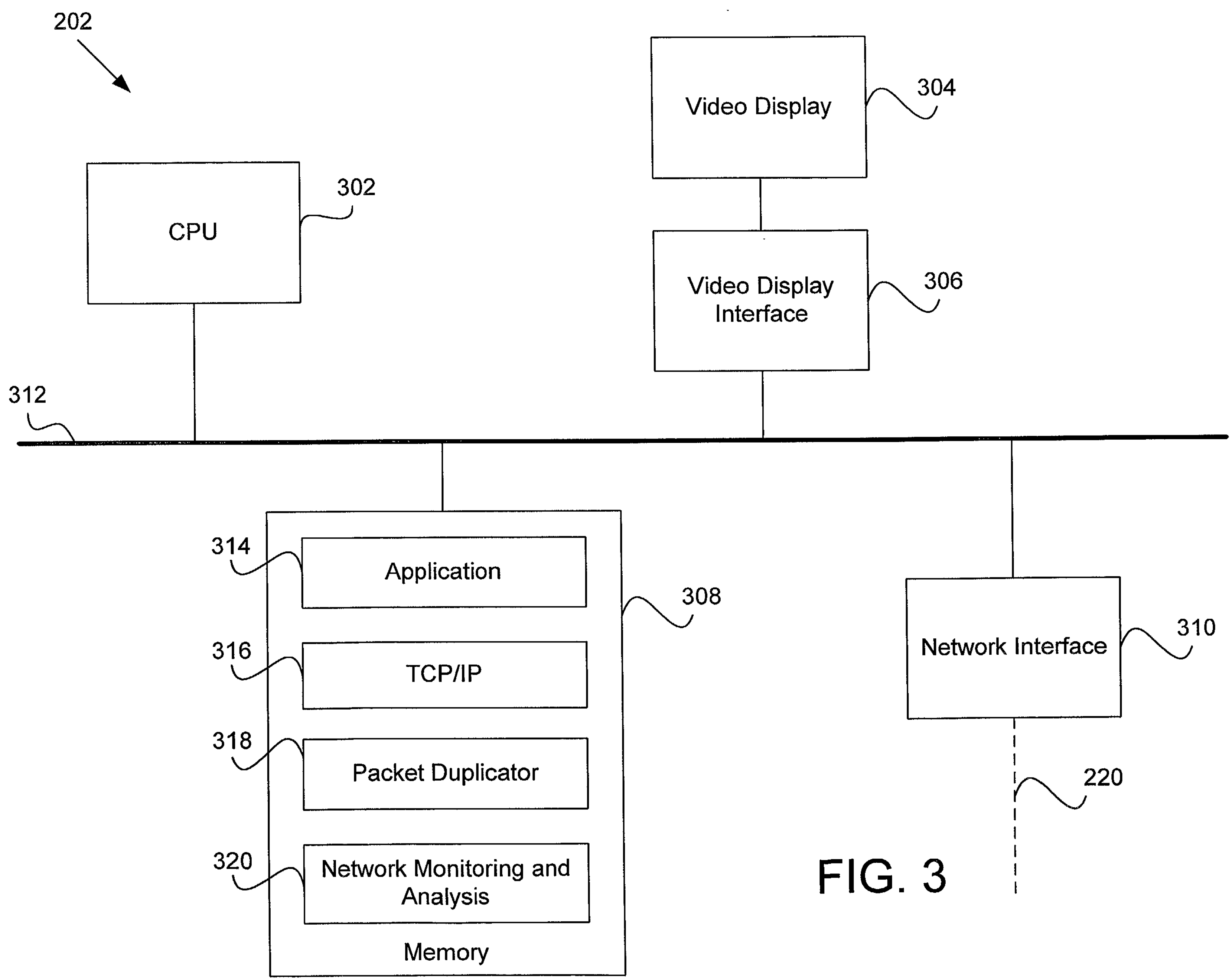

202
CPU
302
312
Video Display
304
Video Display Interface
306
Application
314
TCP/IP
316
Packet Duplicator
318
Network Monitoring and Analysis
320
Memory
308
Network Interface
310
220

FIG. 3

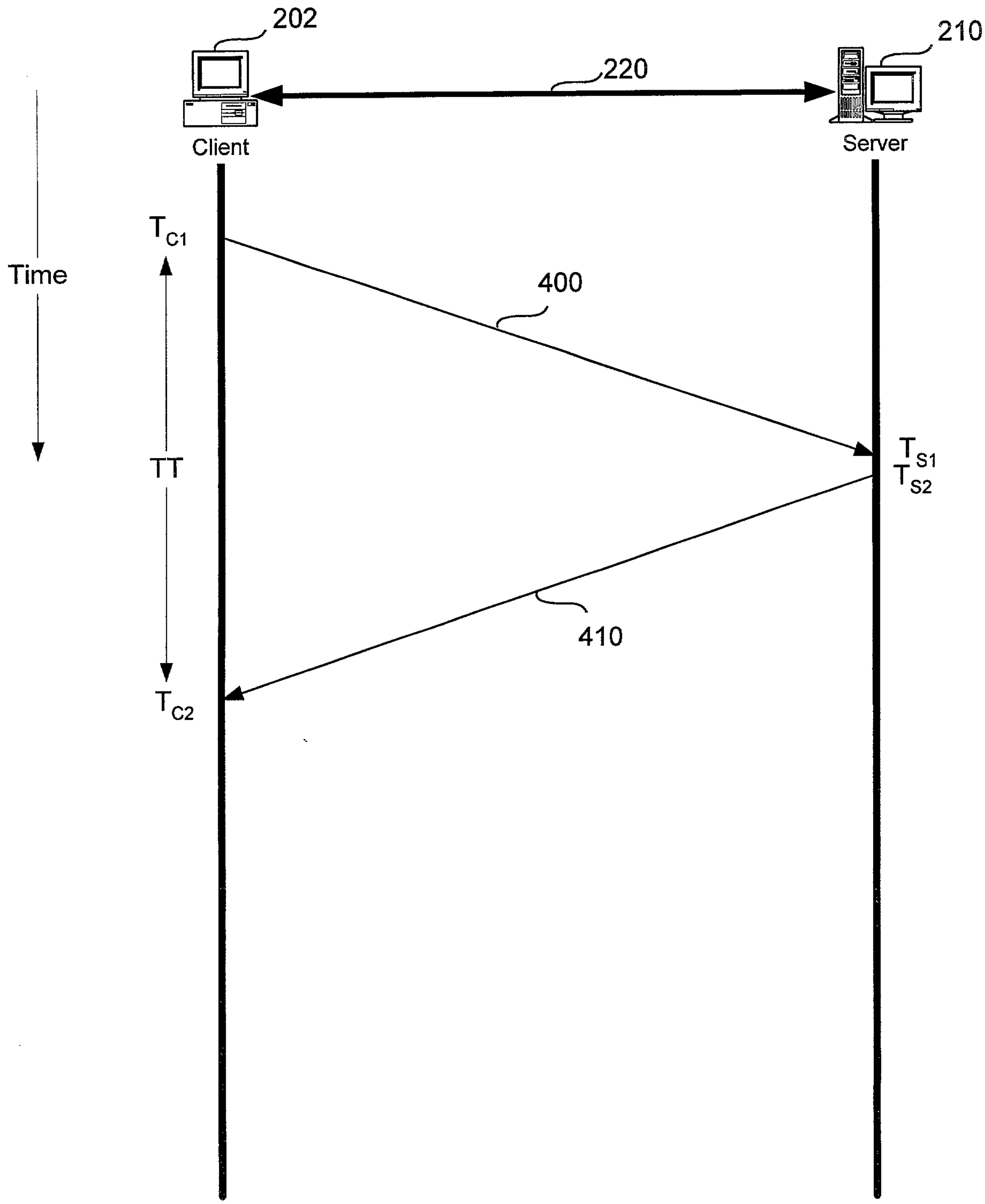
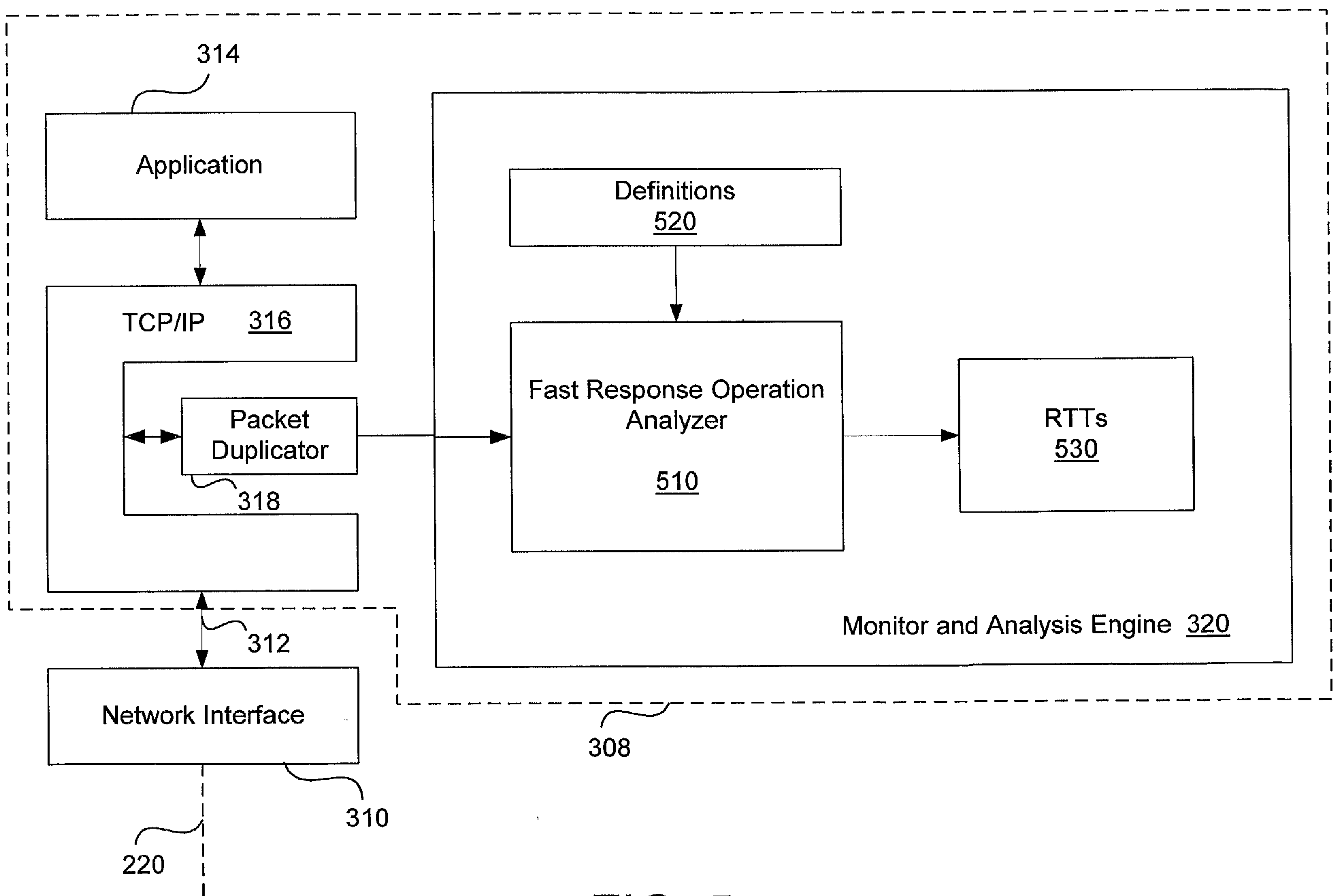


FIG. 4



314
Application
TCP/IP 316
Packet Duplicator
318
312
Network Interface
310
220
Definitions 520
Fast Response Operation Analyzer
510
RTTs 530
Monitor and Analysis Engine 320
308

FIG. 5

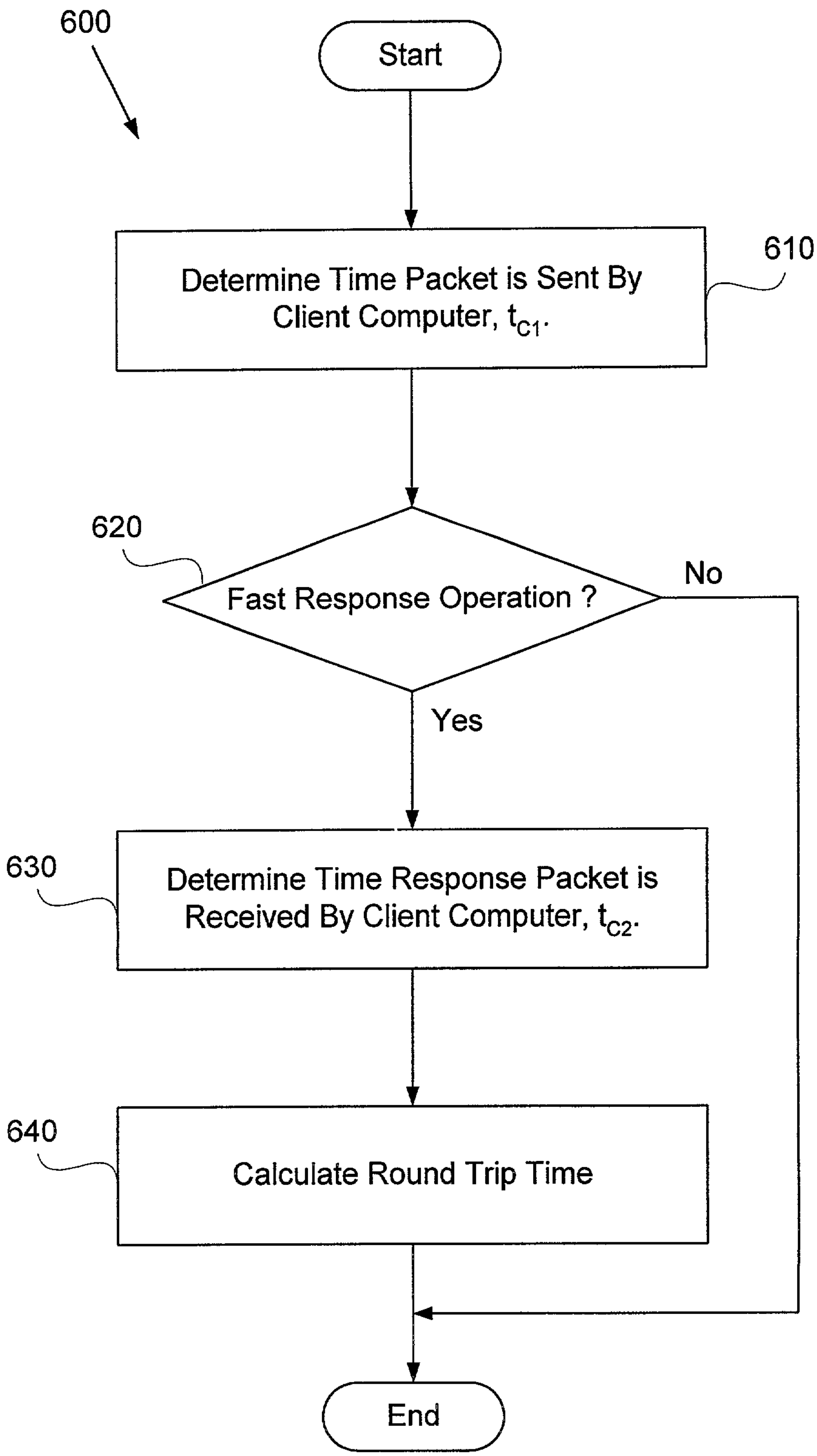

600
Start
Determine Time Packet is Sent By Client Computer, t_{C1}.
610
620
Fast Response Operation ?
No
Yes
630
Determine Time Response Packet is Received By Client Computer, t_{C2}.
640
Calculate Round Trip Time
End

FIG. 6